Concrete Technology
Lecture 3

TYPES OF CEMENT

Contents

Tests on Cement

- Fineness
- Normal Consistency
- Setting Time
- Soundness
- Strength

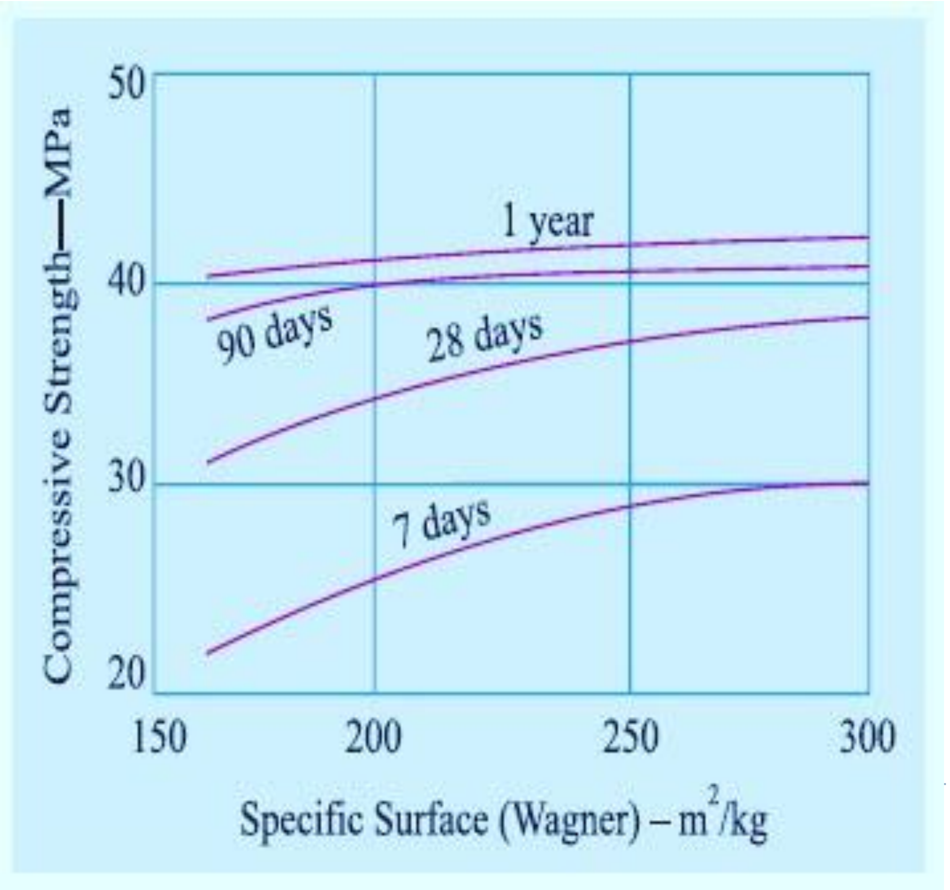
Fineness Test

- Fineness of cement is usually measured in terms of specific surface i.e. the total surface area of all particles in one gram of cement, expressed as cm^2/g or m^2/kg
- The fineness of cement has an important bearing on the rate of hydration, rate of gain of strength, evolution of heat.
- Finer cement offers greater surface area.
- Disadvantage of fine grinding is that it is susceptible to air set & early deterioration
- Maximum no. of particles in a sample of cement<100microns.
- The smallest particle should have a size if 1.5microns.
- Large particle should have a size of 10microns
- The particle size fraction below 3 microns has been found to have the predominant effect on the strength at one day while 3-25 micron fraction has a major influence on the 28 days strength.
- In commercial cement it is suggested that there should be about 25-30 per cent of particles of less than 7 micron in

Fineness Test

- Fineness is measured in two ways

1. By Sieving
2. By Determination of Specific Surface (Air permeability method)



Standard Consistency Test

- For finding out initial setting time, final setting time and soundness of cement, and strength a parameter known as standard consistency has to be used
- The standard consistency of a cement paste as per ASTM C-187 is defined as that consistency which will permit a Vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 10 mm from the top of the mould in 30s after being released.
- The apparatus used for the test is called as Vicat apparatus and is used to find out the percentage of water required to produce a cement paste of standard consistency. This is also called normal consistency (CPNC).

VICAT APPRATUS

Setting Time Test

- An arbitrary division has been made for the setting time of cement.

1. Initial setting time &

2. Final setting time.

Initial Setting Time

- The time elapsed between the moment that the water is added to the cement, to the time that the paste starts losing its plasticity.
- Normally a minimum of 30min has maintained for mixing & handling operations.
- It should not be less than 30min.

Final Setting Time

- The time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure.
- It should not exceed 10hours.
- So that it is avoided from least vulnerable to damages from external activities.

Flash Set vs. False Set

Flash Set

- It is the immediate stiffening of cement paste in a few minutes after mixing with water. It is accompanied by large amount of heat generation upon reaction of C3A with water. Gypsum is added in cement to prevent flash set.

False Set

- It is a rapid development of rigidity of cement paste without generation of much heat. This rigidity can be overcome & plasticity can be regained by further mixing without addition of water. In this way cement paste restores its plasticity & sets in a normal manner without any loss of strength. It may be due to dehydration of gypsum as a result of contacting hot clinker or due to activation of C3S by aeration in high humidity.

Soundness Test

- It is very important that the cement after setting shall not undergo any appreciable change of volume.
- Certain cements have been found to undergo a large expansion after setting causing disruption of the set and hardened mass.
- This will cause serious difficulties for the durability of structures when such cement is used.
- The testing of soundness of cement is to ensure that the cement does not show any appreciable subsequent expansion
- The test is performed by Le-Chatelier test

Soundness Test (Cont'd)

- The unsoundness in cement is due to the presence of excess of lime than that could be combined with acidic oxide at the kiln.
- This is also due to inadequate burning or insufficiency in fineness of grinding or thorough mixing of raw materials.
- It is also likely that too high a proportion of magnesium content or Calcium Sulphate (Gypsum) content may cause unsoundness in cement
- Therefore magnesia content in cement is limited to 6% and Gypsum to 3-5% as excess of Gypsum also leads to expansion

Strength Test

- This is the most important of all properties of hardened cement.
- Due to excessive shrinkage and cracking the strength tests are not made on neat cement paste.
- Standard sand is used for finding the strength of cement.
- ASTM C 109-05 prescribes a cement-sand mix with proportions of 1:2.75 and a water/cement ratio of 0.485, using a standard sand (ASTM C 778-06) for making 51 mm (2 in.) cubes

Minimum Strength Requirements for Cement (MPa (psi))

Age (days)	ASTM C 150–05 (mortar cube), cement type (Table 2.7)							
	I	IA	II[#]	IIA[#]	III	IIIA	IV	V
1	–	–	–	–	12.0	10.0	–	–
	–	–	–	–	(1740)	(1450)	–	–
3	12.0	10.0	10.0	8.0	24.0	19.0	–	8.0
	(1740)	(1450)	(450)	(1160)	(3480)	(2760)	–	(1160)
7	19.0	16.0	17.0	14.0	–	–	7.0	15.0
	(2760)	(2320)	(2470)	(2030)	–	–	(1020)	(2180)
28	28.0[a]	22.0[a]	28.0[a]	22.0[a]	–	–	17.0	21.0
	(4060)	(3190)	(4080)	(3190)	–	–	(2470)	(3050)

* and not more than 52.5 (7600); ** and not more than 62.5 (9100)

[#] Strength values depend on specified heat of hydration or chemical limits of tricalcium silicate and tricalcium aluminate

[a] Optional

Types of Cement

- ASTM Classification
- Super-sulfated (Slag) Cement
- Portland-Pozzolan Cements
- Air Entraining Cement
- Expansive Cements
- High Alumina Cement

ASTM CLASSIFICATION

ASTM Type	Classification	Characteristics	Applications
Type I	General purpose	Fairly high C_3S content for good early strength development	General construction (most buildings, bridges, pavements, precast units, etc)
Type II	Moderate sulfate resistance (Modified cement)	Low C_3A content (<8%)	Structures exposed to soil or water containing sulfate ions
Type III	High early strength (Rapid-hardening)	Ground more finely, may have slightly more C_3S	Rapid construction, cold weather concreting
Type IV	Low heat of hydration (slow reacting)	Low content of C_3S (<50%) and C_3A	Massive structures such as dams. Now rare.
Type V	High sulfate resistance	Very low C_3A content (<5%)	Structures exposed to high levels of sulfate ions

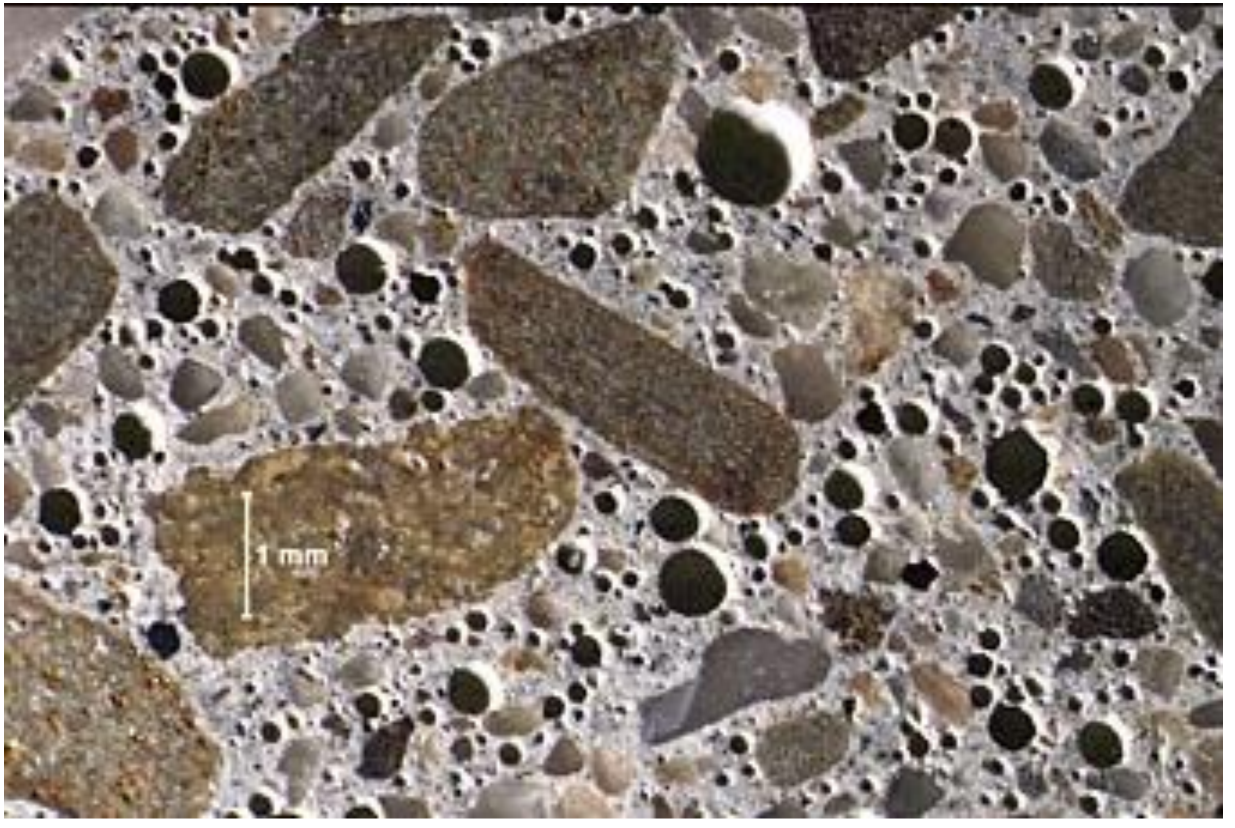
Chemical Composition of main types of Portland Cement

ASTM Type		C_3S %	C_2S %	C_3A %	C_4AF %	B. Fineness Kg/m2
I	General Purpose	55	19	10	7	370
II	Mod Sulfate Mod Heat	51	24	6	11	370
III	Early Strength	56	19	10	7	540
IV	Low Heat	28	49	4	12	380
V	Sulfate Resistant	38	43	4	9	380

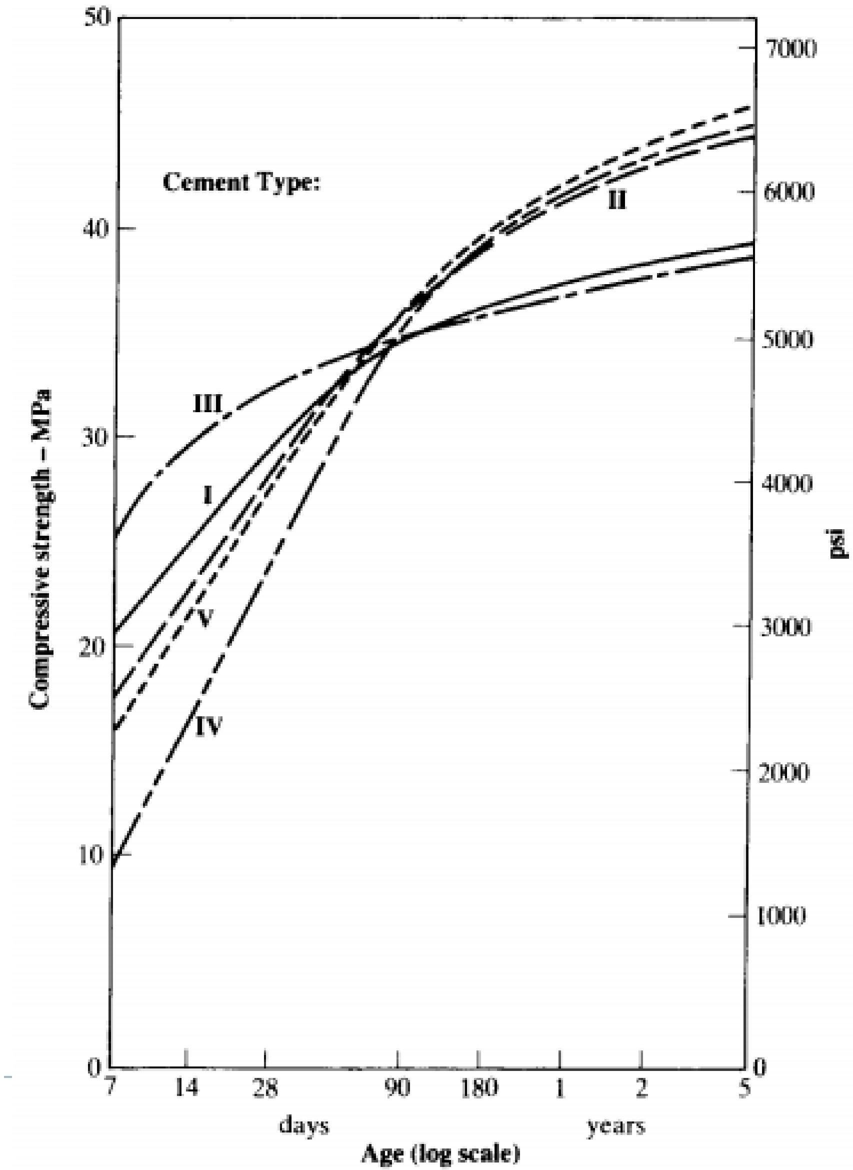
Type IA, IIA or IIIA

- These cements have same composition as Types I, II, and III, respectively, except that small quantities of air-entraining material are inter-ground with the clinker during manufacture.
- These cements produce concrete with minute, well distributed and separated air bubbles which improve the resistance to freeze-thaw action and to scaling caused by chemicals applied for snow and ice removal.

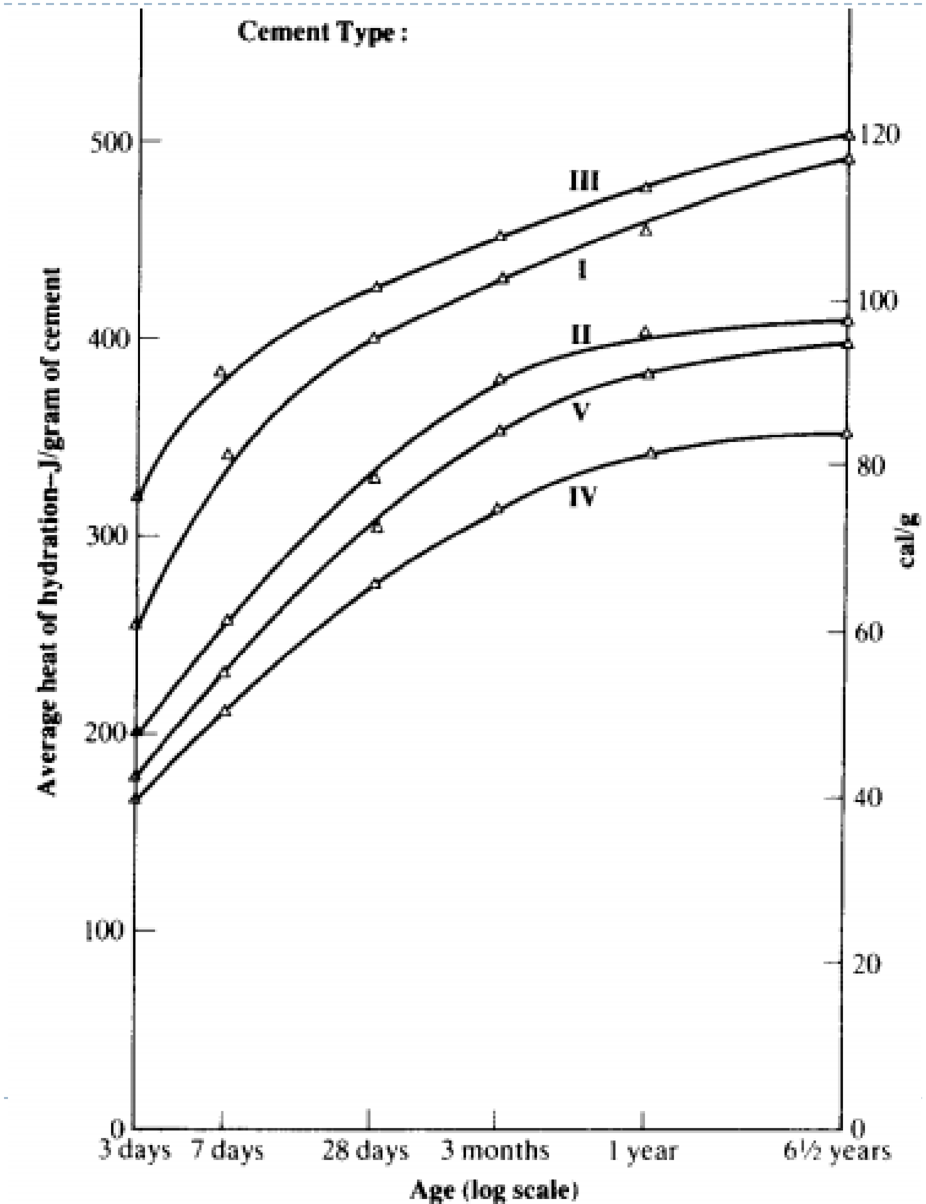
Air Entrained Concrete



Strength Development of different types of cement



Development of heat of Hydration of different cement types



White and Colored Portland Cement

- It has composition same as Type I or Type III cement, except that it has a white color instead of gray color.
- It is made of selected raw materials containing negligible amounts of iron and magnesium oxides the substances that give cement its gray colors.
- It is used primarily for architectural purposes.

White Cement

Super-sulfated (Slag) Cement

- It is made from granulated blast-furnace slag
- The advantages of super-sulfated cement lie in a high resistance to sea water and to sulfate attack, as well as to peaty acids and soils.
- The use of this cement requires particular attention as its rate of strength development is strongly affected at low and high temperatures, and
- The cement has to be stored under very dry conditions as otherwise it deteriorates rapidly.

Slag

Blast furnace Slag

Blast Furnace Slag Cement

Portland Pozzolan Cements

- These cements are made by inter-grinding or blending pozzolans with Portland cement.
- *Pozzolan* is a siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of water, chemically react with calcium hydroxide (liberated by hydrating Portland cement) at ordinary temperatures to form compounds possessing cementitious properties
- Fly ash is a Pozzolan which is generated as a waste material in thermal power station when powdered coal is used as fuel
- Other pozzolanic materials are Rice Husk Ash. Metakaolin and Silica Fume

FlyAsh

Rice Husk Ash

Metakaolin

Kaolinite

Metakaolin

Silica Fume

Portland Pozzolan Cements (Cont'd)

- Portland pozzolan cement produces less heat of hydration and offers greater resistance to the attack of aggressive waters than ordinary Portland cement. Moreover, it reduces the leaching of calcium hydroxide when used in hydraulic structures. It is particularly useful in marine and hydraulic construction and other mass concrete constructions. Portland pozzolana cement can generally be used where ordinary Portland cement is usable.
- Portland-pozzolan cements gain strength slowly and therefore require curing over a comparatively long period, but the long-term strength is high

EFFLORESCENCE AND LEACHING IN CONCRETE

Reduction of Lime during Curing

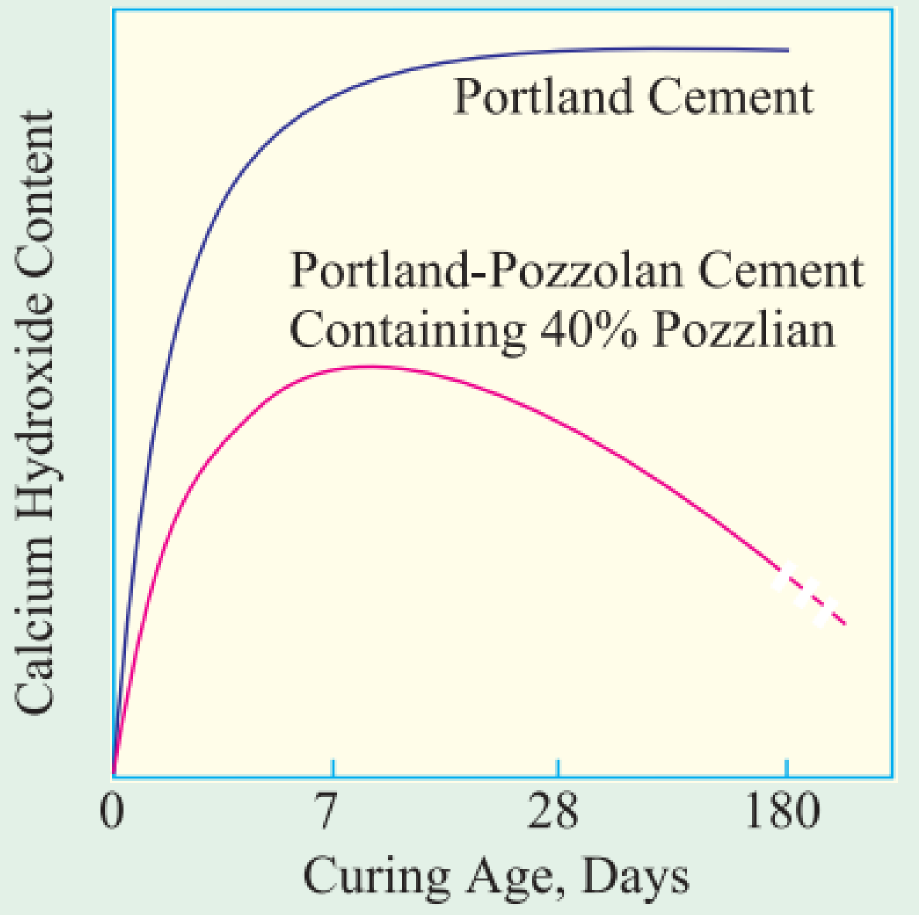
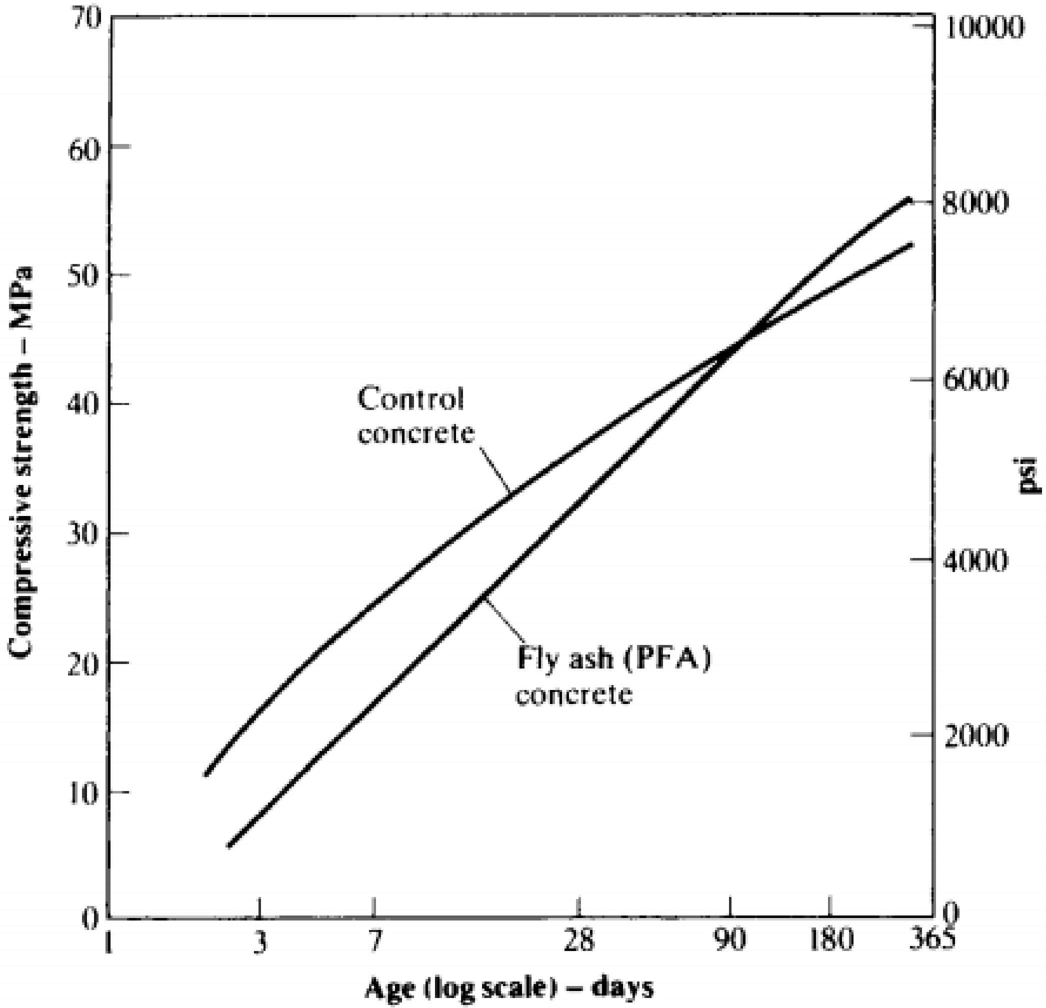


Fig. 2.1. Shows typical reduction of $Ca(OH)_2$

Strength development of OPC vs Portland Pozzolan Cement



Typical relative rates of strength development of Portland cement (control) concrete and concrete with fly ash (PFA) replacement

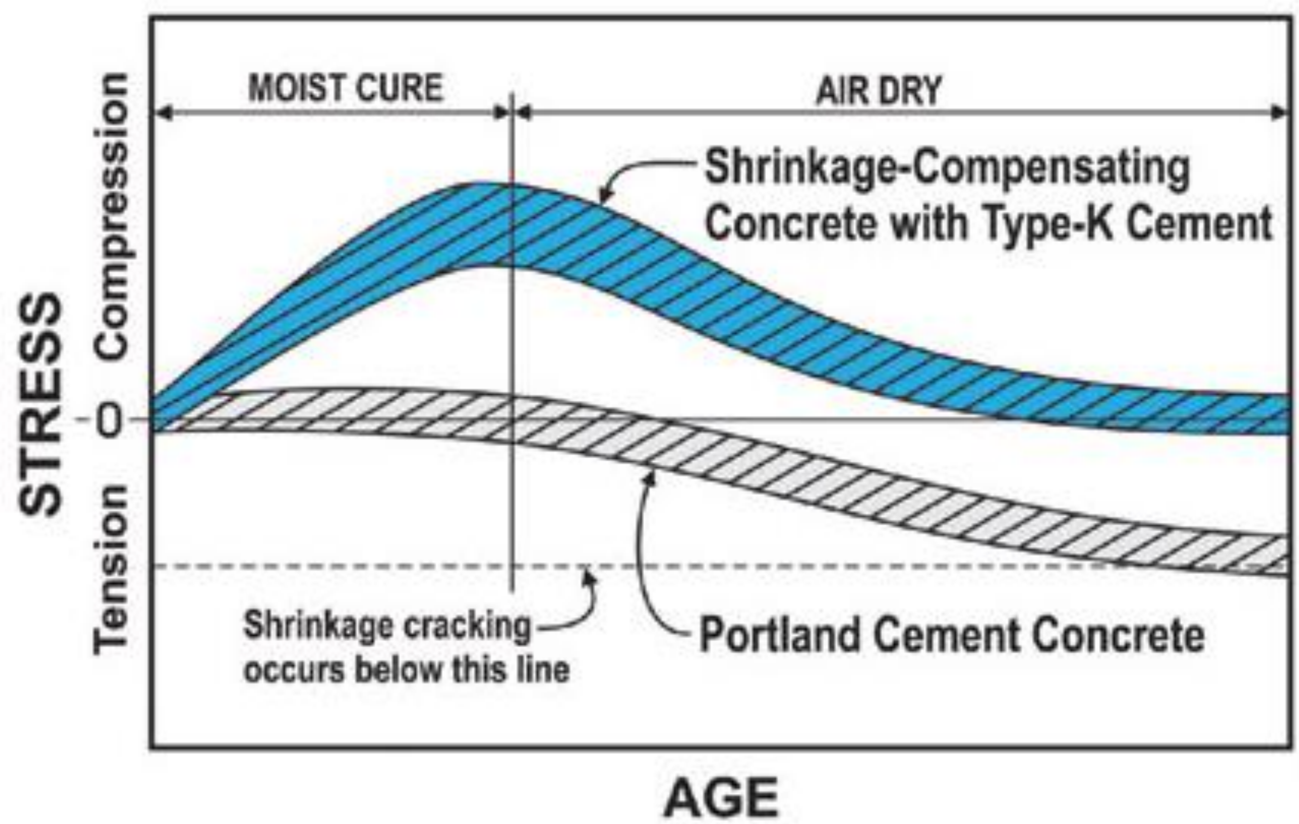
Expansive Cements

- Concrete made with ordinary Portland cement shrinks while setting due to loss of free water. Concrete also shrinks continuously for long time. This is known as drying shrinkage
- Cement used for grouting machine foundations, if shrinks, the purpose for which the grout is used will be to some extent defeated
- For many purposes, it would be advantageous to use a cement which does not change its volume due to drying shrinkage (and thus to avoid cracking) or, in special cases, even expands on hardening
- Expansive cements consist of a mixture of Portland cement, expanding agent and stabilizer. The expanding agent is obtained by burning a mixture of gypsum, bauxite and chalk and blast furnace slag is used as a stabilizer.

Expansive Cements (Cont'd)

- One type of expansive cement is known as shrinkage compensating cement.
- This cement when used in concrete, with restrained expansion, induces compressive stresses which approximately offset the tensile stress induced by shrinkage.
- Another similar type of cement is known as Self Stressing cement.
- This cement when used in concrete induces significant compressive stresses after the drying shrinkage has occurred.
- The induced compressive stresses not only compensate the shrinkage but also give some sort of prestressing effects in the tensile zone of a flexural member.

Comparison between Portland Cement Concrete and Shrinkage Compensating Concrete



High-Alumina Cement (HAC)

- High-alumina cement was developed at the beginning of the previous century to resist sulfate attack but it soon became used as a very rapid-hardening cement
- HAC is manufactured from limestone or chalk and bauxite
- About 80 per cent of its ultimate unconverted strength is reached at the age of 24 hours, and even at 6 to 8 hours, sufficient strength is achieved for the removal of formwork.
- The rapid hydration produces a high rate of heat development, which is about *2.5* times that of rapid- hardening Portland (Type III) cement, although the total heat of hydration is of the same order for both types of cement.
- HAC is slow setting but the final set follows the initial set more rapidly than in Portland cement
- Also effective water cement ratio has a huge impact on the development of strength of HAC

THE END